✭ TUTORIAL 3: ELECTRIC POTENTIAL ✭

i) Consider a **uniformly charged (solid) sphere** with total charge *Q* and radius *R,* centered at the origin. You solved for E(r) in a recent homework, and should have found the following:

$$E(r)=\begin{cases}\dfrac{Q}{4\pi\varepsilon_0 R^3}r & \text{for r<R}\\ \dfrac{Q}{4\pi\varepsilon_0 r^2} & \text{for r>R}\end{cases}$$

Which aspects of this formula now seem "obvious" to you?

What's the <u>principle of physics</u> used to generate this formula?

(If you're not <u>sure</u> of any details, take the time at home to rederive it from scratch!)

ii) The definition of voltage (potential) says $V(r)=-\int_O^r \vec{E}\cdot d\vec{L}$.

Choosing V(∞)=0 (i.e. setting "O"= ∞ in this formula), this is easy enough to find if r>R:

If r>R, $V(r)=-\int_\infty^r \vec{E}\cdot d\vec{L}=-\int_\infty^r \frac{Q}{4\pi\varepsilon_0 r^2}dr=+\frac{Q}{4\pi\varepsilon_0}\frac{1}{r}\Big|_\infty^r=+\frac{Q}{4\pi\varepsilon_0 r}$

- Don't just accept the details - check my math please!

Talk with your neighbors, or us, about any piece that seem at all confusing to you.

iii) If r<R, I need to break that integral up into two pieces **<u>(why?),</u>** giving:

If r<R, $V(r)=-\int_\infty^r \vec{E}\cdot d\vec{L}$

$$=-\int_\infty^R \vec{E}\cdot d\vec{L}-\int_R^r \vec{E}\cdot d\vec{L}$$

$$=-\int_\infty^R \frac{Q}{4\pi\varepsilon_0 r^2}dr-\int_R^r \frac{Q}{4\pi\varepsilon_0 R^3}r\,dr$$

$$=+\frac{Q}{4\pi\varepsilon_0 R}\qquad-\frac{Q}{4\pi\varepsilon_0 R^3}\frac{r^2}{2}\Big|_R^r$$

$$=\frac{Q}{4\pi\varepsilon_0}\left(\frac{3}{2R}-\frac{r^2}{2R^3}\right)$$

<u>Work through all 5 lines</u>. Make sure you see what is going on at each step .

Talk with your neighbors, or ask us about anything that seem at all confusing to you!

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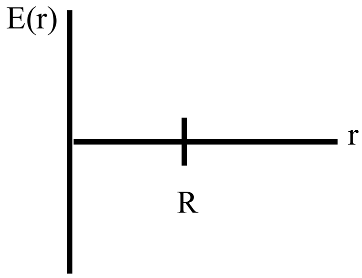
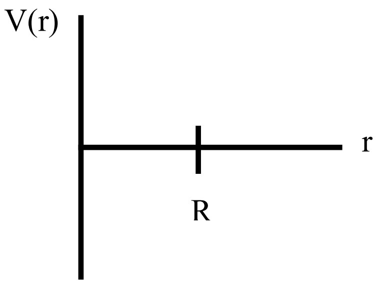
iv) In the space below, sketch E(r) and V(r). (E should be easy. V is harder, be careful!)



- Is E(r) continuous? Is V(r)? Should they be? **Why/why not?**

- Are their derivatives continuous? Should they be?

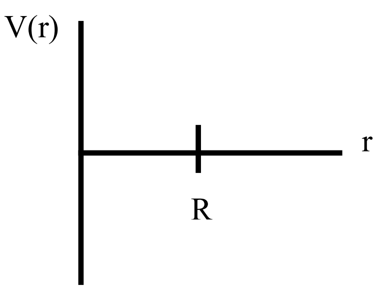


- Do the signs make sense *everywhere* ? **Explain!**

- Is the behavior of E(r) and V(r) at large r correct?

- What's the "slope" of V(r) at the origin? (What should it be?)

Now let **the origin** (r=0) be your choice of zero voltage, and re-sketch this *V* as a function of *r*.



Explain how(if) the choice of zero voltage at the origin changes the electric field.

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